CLAIMS

1. (Currently Amended) Wireless radiofrequency data communication system comprising:

- a base-station comprising a multiple of N first groups and a signal processing-unit comprising memory means and processing means, wherein each first group comprises a receiver-unit provided with a receiver and at least one antenna which is connected to the receiver-unit, wherein the signal processing-unit is connected with each of the first groups for processing receive-signals generated by each of the first groups, and
- a multiple of M second groups for transmitting radiofrequency signals to the first groups, wherein each second group comprises a transmitter-unit provided with a transmitter and at least one antenna which is connected to the transmitter-unit,

wherein the memory means of the signal processing-unit are provided with means comprising information about the transfer-functions of radiofrequency signals from each of the antennas of the second groups to each of the antennas of the first groups, and wherein the transmitters and receivers operate on essentially the same radiofrequency or radiofrequency-band,

characterised in that,

the signal processing-unit is arranged to process, in use, the receive-signals on the basis of the Maximum Likelihood Detection method, such that for each second group of the second groups an individual communication channel is formed with the base-station wherein these communication channels are generated simultaneously and separately from each ~~other.~~other;

wherein each transmitter comprises means for modulating an information signal on a radiofrequency signal according to the Quadrature Amplitude Modulation (QAM) method, wherein so-called QAM-symbols are transmitted, and wherein each receiver comprises means for demodulating information signals from a received radiofrequency signal; and

wherein the signal processing-unit is arranged to calculate, in use, a detection signal $\mathbf{x}_{DET}$ according to

$$\mathbf{x}_{DET} = arg_{over\ set}\ min(\|\mathbf{r} - \mathbf{H}\ \mathbf{x}^p_{SET}\|), \qquad \textbf{(A)}$$

where $arg_{over\ set}\ min(\|...\|)$ is a function which, according to **(A)**, yields that vector $\mathbf{x}_{DET}$ out of a set $\mathbf{X}_{SET}$ of P vectors $\mathbf{x}^p_{SET}$ (p=1,..,P) for which the length $\|\mathbf{r} - \mathbf{H}\ \mathbf{x}^p_{SET}\|$ of the complex N-dimensional vector $\mathbf{r} - \mathbf{H}\ \mathbf{x}^p_{SET}$ is minimal, wherein $\mathbf{r}$ is a complex N-dimensional vector $[r_1,...,r_i,...,r_N]^T$ with r_i being the signal received by the i^{th} first group of the N first groups, $\mathbf{H}$ is a complex [N × M] matrix containing transfer-functions h_{im} (i=1,...,N; m=1,...,M), wherein h_{im} is the transfer-function for transmission from the m^{th} second group of the M second groups to the i^{th} first group of the N first groups, and where $\mathbf{x}^p_{SET}$ is the p^{th} complex M-dimensional vector $[x^p_{SET,1},...,x^p_{SET,m},...,x^p_{SET,M}]^T$ of the set $\mathbf{X}_{SET}$, wherein the vectors x^p_{SET} in the set $\mathbf{X}_{SET}$ contain possible combinations of values which can be assigned by the second groups to an information signal $\mathbf{x}$, where $\mathbf{x}$ is a M-dimensional vector $[x_1,...,x_m,...,x_M]^T$ with x_m being the information signal transmitted by the m^{th} second group of the M second groups to the first groups and where x_m is one individual communication signal.

2. (Canceled)

3. (Canceled)

4. (Currently Amended) Wireless radiofrequency data communication system according to claim 1~~3~~, characterised in that, the processing unit is arranged to apply, in use, the following approximation **(B)** in the calculation of **(A)**

$$\|\mathbf{r}\text{-}\mathbf{H}\ \mathbf{x}^p_{SET}\| = \Sigma_{i=1,..,N}\left(\|Real([\mathbf{r}\text{-}\mathbf{H}\ \mathbf{x}^p_{SET}]_i)\| + \|Im([\mathbf{r}\text{-}\mathbf{H}\ \mathbf{x}^p_{SET}]_i)\|\right), \qquad \textbf{(B)}$$

wherein $\Sigma_{i=1,..,N}(...)$ is a summation over the index i from 1 to N over the argument $(\|Real([\mathbf{r}\text{-}\mathbf{H}\ \mathbf{x}^p_{SET}]_i)\| + \|Im([\mathbf{r}\text{-}\mathbf{H}\ \mathbf{x}^p_{SET}]_i)\|)$, where $\|(.)\|$ yields the absolute value of its input argument and where *Real(...)* is a function which, in equation **(B)**, yields the real part of its complex argument $[\mathbf{r} - \mathbf{H}\ \mathbf{x}^p_{SET}]_i$, with $[\mathbf{r} - \mathbf{H}\ \mathbf{x}^p_{SET}]_i$ being the i^{th} component of

the complex N-dimensional vector $\mathbf{r}$ - $\mathbf{H}$ $\mathbf{x}^{p}_{SET}$, and where *Im(...)* is a function which, in equation **(B)**, yields the imaginary part of its complex argument $[\mathbf{r} - \mathbf{H}\, \mathbf{x}^{p}_{SET}]_i$.

5. (Original) Wireless radiofrequency data communication system according to claim 4, characterised in that, the set $\mathbf{X}_{SET}$ comprises all possible combinations of values which can be assigned to the signal $\mathbf{x}$ by the second groups.

6. (Original) Wireless radiofrequency data communication system according to claim 4, characterised in that, the signal processing-unit is arranged to find, in use, the detection signal $\mathbf{x}_{DET}$ according to a Reduced Search Technique wherein a search-tree is passed through according to the following steps 1 to 7:

- **Step 1**: calculate the lengths of the complex vectors $\mathbf{v}$ corresponding to all combinations of possible values which can be assigned to $[x_1,..,x_L]$, wherein $\mathbf{v}$ is given by

$$\mathbf{v} = (\mathbf{r} - \textstyle\sum_{i=1,..,L} \mathbf{h}_i * x^{p}_{SET,\,i}), \qquad \textbf{(C)}$$

where $\sum_{i=1,..,L}$ (...) is a summation over the index i from 1 to L over the complex argument $[\mathbf{h}_i * x^{p}_{SET,\,i}]$ and where $\mathbf{h}_i$ is the i^{th} column $[h_{1,i},...,h_{N,i}]^T$ of the matrix $\mathbf{H}$;

- **Step 2**: select the K combinations of values for $[x^{p}_{SET,\,1},.., x^{p}_{SET,\,L}]$ corresponding to the K smallest lengths of $\mathbf{v}$ as well as the K vectors $\mathbf{v}$ itself and set m = L+1;
- **Step 3**: calculate the lengths of the C*K new vectors $\mathbf{v}$ given by

$$\mathbf{v} = \mathbf{v}_{old} - \mathbf{h}_m * x^{p}_{SET,\,m}, \qquad \textbf{(D)}$$

where $\mathbf{v}_{old}$ is one of the K vectors $\mathbf{v}$ resulting from the preceding step and where h_m is the m^{th} column of $\mathbf{H}$;

- **Step 4**: select those K combinations of values for $[x^{p}_{SET,\,1},.., x^{p}_{SET,\,m}]$ that correspond to the K smallest lengths of $\mathbf{v}$ as well as the K vectors $\mathbf{v}$ itself and set $m = m_{old} + 1$, where m_{old} is m from the preceding step;
- **Step 5**: if m<M then go to Step 3, else go to step 6;
- **Step 6**: calculate the lengths of the C*K new vectors $\mathbf{v}$ given by

$$\mathbf{v} = \mathbf{v}_{old} - \mathbf{h}_M * x^{p}_{SET,\,M}, \qquad \textbf{(E)}$$

- **Step 7:** the detection signal $\mathbf{x}_{DET}$ is determined as that combination of values $\mathbf{x}_{DET} = [x^{p}_{SET,\,1},.., x^{p}_{SET,\,M}]$ which corresponds to the vector $\mathbf{v}$ with the smallest length,

wherein K and L are predetermined fixed integer values which control the size P of the set $\mathbf{X}_{SET}$ and wherein the constellation size C of the system is the number of values $x^{P}_{SET,m}$ which can be assigned by one of the second groups to one component x_m (m=1,..,M) of $\mathbf{x}$ and where $\mathbf{v}_{old}$ is one of the K vectors $\mathbf{v}$ resulting from Step 3, the calculated detection signal $\mathbf{x}_{DET}$ is the combination of values $\mathbf{x}^{P}_{SET}$ corresponding to the smallest vector $\mathbf{v}$.

7. (Currently Amended) Wireless radiofrequency data communication system according to claim 4, characterised in that, the signal processing-unit is arranged to find, in use, the detection signal $\mathbf{x}_{DET}$ according to a Reduced Search Technique wherein a search-tree is passed through according to the following steps 1 to 7:

- **Step 1**: calculate the values of the lengths of the C vectors $\mathbf{v}$ according to the C possible values $x^{P}_{SET,1}$

$$\mathbf{v} = (\mathbf{r} - \mathbf{h}_1 * x^{P}_{SET,1}), \qquad \mathbf{(F)}$$

wherein $\mathbf{h}_1$ is the first column of $\mathbf{H}$;

- **Step 2**: select those combinations of values for $x^{P}_{SET,1}$ for which the lengths of $\mathbf{v}$ are smaller than T, as well as the corresponding vectors $\mathbf{v}$ and set m=2;
- **Step 3**: calculate the lengths of the new vectors $\mathbf{v}$ given by

$$\mathbf{v} = \mathbf{v}_{old} - \mathbf{h}_m * x^{P}_{SET,m}, \qquad \mathbf{(G)}$$

wherein $\mathbf{v}_{old}$ is one of the vectors $\mathbf{v}$ resulting from the preceding step and where $\mathbf{h}_m$ is the m^{th} column of $\mathbf{H}$, and adjust the ~~treshold~~ threshold T;

- **Step 4**: select those combinations of values for $[x^{P}_{SET,1},..., x^{P}_{SET,m}]$ for which $\mathbf{v}$ is smaller than T, discard the other combinations and set m = m_{old} + 1, where m_{old} is m from the preceding step;
- **Step 5**: if m<M then go to Step 3, else go to step 6,
    - **Step 6**: calculate the lengths of the new vectors $\mathbf{v}$ given by

$$\mathbf{v} = \mathbf{v}_{old} - \mathbf{h}_M * x^{P}_{SET,M}, \qquad \mathbf{(H)}$$

- **Step 7:** the detection signal $\mathbf{x}_{DET}$ is determined as that combination of values $\mathbf{x}_{DET} = [x^{P}_{SET,1},.., x^{P}_{SET,M}]$ which corresponds to the vector $\mathbf{v}$ with the smallest length, wherein T is a predetermined fixed threshold value which controls the size P of the set $\mathbf{X}_{SET}$ and wherein the constellation size C of the system is the number of values $x^{P}_{SET,m}$

which can be assigned by one of the second groups to one component x_m (m=1,..,M) of ~~x~~ ~~,and~~ x, and wherein $\mathbf{v}_{old}$ is one of the vectors **v** resulting from step 3, the calculated detection signal $\mathbf{x}_{DET}$ is the combination of values $\mathbf{x}^P_{SET}$ corresponding to the smallest vector **v**.

8. (Original) Wireless radiofrequency data communication system according to claim 4, characterised in that, the signal processing-unit is arranged to find, in use, the detection signal $\mathbf{x}_{DET}$ according to a Reduced Search Technique which at least comprises the following steps:

- **Step A1:** calculate the inner product z between the vector **r** and the u^{th} column $\mathbf{h}_u$ of the matrix **H**, where u is an integer 1(u(M, according to:

$$z = \mathbf{h}^*_u \mathbf{r}, \qquad \textbf{(I)}$$

where $\mathbf{h}^*_u$ is the complex conjugated and transposed of $\mathbf{h}_u$;

- **Step A2:** calculate C^{M-1} terms Interf corresponding to all possible value combinations which can be assigned to $[x_1,\ldots,x_{u-1},x_{u+1},\ldots,x_M]$, wherein the terms Interf are defined according to:

$$\text{Interf} = \Sigma_{(i=1,..,M\ \wedge\ i\neq u)}\ x_i *(\mathbf{h}^*_u * \mathbf{h}_i), \qquad \textbf{(J)}$$

wherein $\Sigma_{(i=1,..,M\ \wedge\ i\neq u)}$ is a summation over the index i from 1 to M with the exception of the integer u;

- **Step A3:** estimate, on the basis of the equations **(I)**, **(J)** and z' according to:

$$z' = \text{Interf} + x_u *(\mathbf{h}^*_u * \mathbf{h}_u), \qquad \textbf{(K)}$$

where z' is an approximation of z, the value for x_u corresponding to each of the value combinations $[x_1,\ldots,x_{u-1},x_{u+1},\ldots,x_M]$, and constitute a test set $\mathbf{X}_{SET}$ comprising C^{M-1} vectors x^P_{SET}, wherein each vector x^P_{SET} represents a value combination $[x_1,\ldots,x_{u-1},x_u,x_{u+1},\ldots,x_M]$;

- **Step A4:** determine the detection signal $\mathbf{X}_{DET}$ according to equation ~~**(A)**~~**(I)**, wherein the test set is defined with the C^{M-1} vectors x^P_{SET} from the preceding step.

9. (New) A method of decoding data encoded in a plurality of transmitted signals transmitted by one or more transmitters and received by one or more receivers as a plurality of received signals, the transmitted signals having encoded therein a plurality of symbols, the method comprising:

(a) calculating a first vector length for each of a plurality of complex vectors corresponding to a constellation having a plurality of combinations of possible data values;

(b) selecting a subset of the combinations based on the first vector lengths calculated in step (a);

(c) calculating, for the first transmitter, a second vector length for each complex vector corresponding to a combination in the subset;

if there are one or more other transmitters, then, for each other transmitter, implementing steps (d) and (e), wherein:

step (d) comprises reducing the subset based on the second vector lengths calculated in step (c); and

step (e) comprises calculating, for a current transmitter, a second vector length for each complex vector corresponding to a combination in the reduced subset; and

(f) generating the data based on the combination of possible data values that corresponds to the complex vector having the smallest second vector length in the subset.

10. (New) The invention of claim 9, wherein:

the subset of combinations selected in step (b) corresponds to a first specified number of complex vectors having the smallest first vector lengths; and

the reduced subset of combinations selected in step (d) corresponds to a second specified number of complex vectors having the smallest second vector lengths.

11. (New) The invention of claim 10, wherein the method is performed with knowledge, prior to the occurrence of step (a), of the number of repetitions of steps (d) and (e) needed to generate the data in step (f).

12. (New) The invention of claim 10, wherein:

the first vector length is given by $||\mathbf{r} - \mathbf{H}\ \mathbf{x}^{p}_{SET}||$, where:

$\mathbf{r}$ is a complex N-dimensional complex vector $[r_1,\ldots,r_i,\ldots,r_N]^T$ with r_i being the signal received by the i^{th} receiver;

$\mathbf{N}$ is the number of receivers;

$\mathbf{H}$ is a complex $[N \times M]$ matrix containing transfer-functions h_{im} $(i=1,\ldots,N;$ $m=1,\ldots,M)$, wherein h_{im} is the transfer-function for transmission from the m^{th} transmitter to the i^{th} receiver;

$\mathbf{M}$ is the number of transmitters; and

$\mathbf{x}^{p}_{SET}$ is the p^{th} M-dimensional complex vector $[x^{p}_{SET,1},\ldots,x^{p}_{SET,m},\ldots,x^{p}_{SET,M}]^T$ of the set $\mathbf{X}_{SET}$, wherein the complex vectors $\mathbf{x}^{p}_{SET}$ in the set $\mathbf{X}_{SET}$ contain possible combinations of values that can be assigned by the one or more transmitters to an information signal $\mathbf{x}$; and

the second vector length is given by $||\mathbf{v}_{old} - \mathbf{h}_m * x^{p}_{SET,m}||$, where:

$\mathbf{v}_{old}$ is one of the complex vectors in the subset; and

h_m is the m^{th} column of $\mathbf{H}$, where m corresponds to the current transmitter.

13. (New) The invention of claim 10, wherein the second specified number of complex vectors is less than the first specified number of complex vectors.

14. (New) The invention of claim 9, wherein:

the subset of combinations selected in step (b) corresponds to the complex vectors having first vector lengths smaller than a first specified threshold; and

the reduced subset of combinations selected in step (d) corresponds to the complex vectors having second vector lengths smaller than a second specified threshold.

15. (New) The invention of claim 14, wherein the method is performed with no knowledge, prior to the occurrence of step (a), of the number of repetitions of steps (d) and (e) needed to generate the data in step (f).

16. (New) The invention of claim 14, wherein:

the first vector length is given by $||\mathbf{r} - \mathbf{H}\ \mathbf{x}^{p}_{SET}||$, where:

$\mathbf{r}$ is a complex N-dimensional complex vector $[r_1,...,r_i,...,r_N]^T$ with r_i being the signal received by the i^{th} receiver;

$\mathbf{N}$ is the number of receivers;

$\mathbf{H}$ is a complex $[N \times M]$ matrix containing transfer-functions h_{im} ($i=1,...,N$; $m=1,...,M$), wherein h_{im} is the transfer-function for transmission from the m^{th} transmitter to the i^{th} receiver;

$\mathbf{M}$ is the number of transmitters; and

$\mathbf{x}^{p}_{SET}$ is the p^{th} M-dimensional complex vector $[x^{p}_{SET,1},...,x^{p}_{SET,m},...,x^{p}_{SET,M}]^T$ of the set $\mathbf{X}_{SET}$, wherein the complex vectors $\mathbf{x}^{p}_{SET}$ in the set $\mathbf{X}_{SET}$ contain possible combinations of values that can be assigned by the one or more transmitters to an information signal $\mathbf{x}$; and

the second vector length is given by $||\mathbf{v}_{old} - \mathbf{h}_m * x^{p}_{SET,m}||$, where:

$\mathbf{v}_{old}$ is one of the complex vectors in the subset; and

h_m is the m^{th} column of $\mathbf{H}$.

17. (New) The invention of claim 14, wherein the second specified threshold is less than the first specified threshold.

18. (New) The invention of claim 9, wherein the signal processing unit calculates the subset by:

(i) calculating an inner product of a complex vector representing the one or more received signals with a complex conjugated and transposed column of a matrix containing transfer functions representing transmission between the one or more transmitters and the one or more receivers;

(ii) calculating, based on a summation of the transmitted signals transmitted by all of the transmitters except for the transmitter corresponding to the complex conjugated and transposed column of the matrix, a plurality of terms corresponding to a plurality of combinations of possible data values that can be assigned to the one or more received signals;

(iii) estimating the inner product calculated in step (i) based on the calculations of steps (i) and (ii); and

(iv) deriving, based on the estimated inner product of step (iii), a subset of complex vectors, each of the complex vectors in the subset representing one of the combinations of possible data values that can be assigned to the one or more received signals.

19. (New) The invention of claim 18, wherein:

the inner product of step (i) is given by $\mathbf{h}^*_u\,\mathbf{r}$, where:

$\mathbf{r}$ is a complex N-dimensional vector $[r_1,\ldots,r_i,\ldots,r_N]^T$ with r_i being the signal received by the i^{th} receiver;

$\mathbf{h}_u$ is the u^{th} column of the matrix $\mathbf{H}$;

$\mathbf{H}$ is a complex $[N \times M]$ matrix containing transfer-functions h_{im} ($i=1,\ldots,N$; $m=1,\ldots,M$), wherein h_{im} is the transfer-function for transmission from the m^{th} transmitter to the i^{th} receiver; and

$\mathbf{M}$ is the number of transmitters;

the plurality of terms of step (ii) is given by $\mathrm{Interf} = \sum_{(i=1,..,M\ \wedge\ i\neq u)} x_i *(\mathbf{h}^*_u * \mathbf{h}_i)$, where:

$\sum_{(i=1,..,M\ \wedge\ i\neq u)}$ is a summation over the index i from 1 to M with the exception of the integer u; and

$\mathbf{h}_i$ is the i^{th} column of the matrix $\mathbf{H}$; and

the estimated inner product of step (iii) is given by $\mathrm{Interf} + x_u *(\mathbf{h}^*_u * \mathbf{h}_u)$, where:

the value for x_u corresponds to each of the value combinations $[x_1,\ldots,x_{u-1},x_{u+1},\ldots,x_M]$ and constitutes a test set comprising a plurality of complex vectors $\mathbf{x}^P{}_{SET}$; and

the subset of complex vectors of step (iv) is derived by

$arg_{over\ set}\ min(\|\mathbf{r} - \mathbf{H}\ \mathbf{x}^P{}_{SET}\|)$, where $arg_{over\ set}\ min(\|\ldots\|)$ is a function identifying the vector having the minimum length in a set of vectors.

20. (New) The invention of claim 9, wherein the number of transmitters and the number of receivers are unequal.

21. (New) The invention of claim 9, wherein the number of transmitters is greater than one, and steps (d) and (e) are implemented more than once.

22. (New) An apparatus for decoding data encoded in a plurality of transmitted signals transmitted by one or more transmitters, the transmitted signals having encoded therein a plurality of symbols, the apparatus comprising:

one or more receivers, each receiver adapted to receive at least one of the transmitted signals and generate one or more received signals; and

a signal processing unit adapted to process the one or more received signals to decode the data by:

(a) calculating a first vector length for each of a plurality of complex vectors corresponding to a constellation having a plurality of combinations of possible data values;

(b) selecting a subset of the combinations based on the first vector lengths calculated in step (a);

(c) calculating, for a first transmitter, a second vector length for each complex vector corresponding to a combination in the subset;

if there are one or more other transmitters, then, for each other transmitter, implementing steps (d) and (e), wherein:

step (d) comprises reducing the subset based on the second vector lengths calculated in step (c); and

step (e) comprises calculating, for a current transmitter, a second vector length for each complex vector corresponding to a combination in the reduced subset; and

(f) generating the data based on the combination of possible data values that corresponds to the complex vector having the smallest second vector length in the subset.

Respectfully submitted,

Date: 3/30/05

Customer No. 46900
Mendelsohn & Associates, P.C.
1515 Market Street, Suite 715
Philadelphia, Pennsylvania 19102

Kevin M. Drucker
Registration No. 47,537
(215) 557-6659 (phone)
(215) 557-8477 (fax)